Evaluation of Stocked Game Fish in the Tanana Valley, 1997

by

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and

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Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft³/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_0
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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ABSTRACT

We estimated the population abundance of rainbow trout *Oncorhynchus mykiss* in two lakes managed to provide trophy-size rainbow trout. The estimated abundance of rainbow trout in Little Harding Lake was 1,157 (SE = 94) of which 80 (SE = 19) were estimated $\geq$ 350 mm tip-of-snout to fork-of-tail (FL). The abundance estimate for rainbow trout in Craig Lake was 179 (SE = 20). Only one captured fish was larger than 350 mm FL. An abundance estimate at Coal Mine #5 was attempted, however was unsuccessful. Of 105 rainbow trout captured at Coal Mine #5 Lake none were from stockings before 1997. Temperature was recorded in four lakes from June to September. None of the measurements exceeded the upper maximum temperature for rainbow trout (25°C). Catch sampling was conducted at Birch, Quartz, and Chena lakes from 1995 to 1997. At Quartz Lake about 80% of the harvest of rainbow trout was comprised of ages 2 and 3 fish. At Birch and Chena lakes more than 50% of the harvest of rainbow trout was comprised of age 1 fish. At all three lakes more than 90% of the harvest of coho salmon *Oncorhynchus kisutch*, was comprised of ages 0 and 1. At Birch Lake coho salmon stocked as fingerlings had the lowest cost-to-the-creel.

Key words: Birch Lake, Chena Lake, Quartz Lake, small lakes, stocking evaluation, Arctic char, *Salvelinus alpinus*, rainbow trout, *Oncorhynchus mykiss*, Arctic grayling, *Thymallus arcticus*, lake trout, *Salvelinus namaycush*, coho salmon, *Oncorhynchus kisutch*, chinook salmon *Oncorhynchus tshawytscha*, growth, days fished, fishing effort, temperature profile, brood table, cohort contribution to the creel, cost benefit comparison.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) stocks game fish in numerous lakes and one stream in the Tanana River Valley within Alaska's interior (Figure 1). Our goal is to provide more angling opportunities near population centers and offer alternatives to the harvest of wild stocks. The stocking program began in the early 1950's, when lakes along the road system were stocked with rainbow trout *Oncorhynchus mykiss*, or coho salmon *O. kisutch*. Today, the stocking program provides diverse year-round sport fishing for rainbow trout, coho salmon, chinook salmon *O. tshawytscha*, Arctic grayling *Thymallus arcticus*, Arctic char *Salvelinus alpinus*, and lake trout *S. namaycush*.
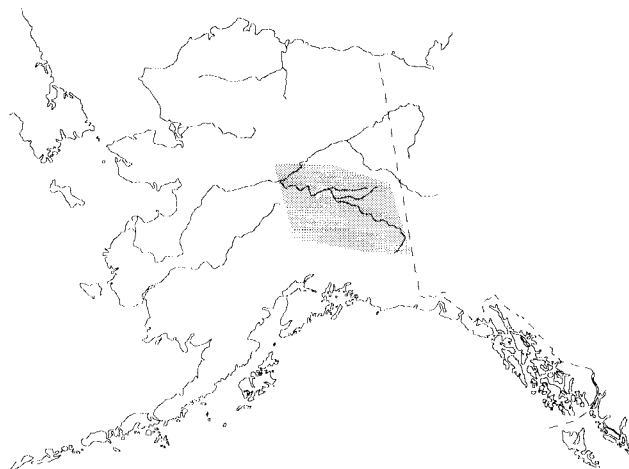
Figure 1.-The Tanana Valley (shaded area).

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The stocking program supports consumptive fisheries along the road system where fishing effort and harvests are highest and serves to divert harvest away from wild populations as a conservation measure. In 1996, an estimated 38,786 anglers fished in the Tanana Valley and they generated an estimated 203,962 angler-days of effort[1] (Howe et al. 1997), second only to the Kenai Peninsula for number of angler-days. An estimated 78,196 angler-days of effort were directed toward stocked fish. The estimated harvests of stocked and wild fish in the Tanana Valley in 1996 were 66,729 and 26,044, respectively. Since 1990 stocked fish represent 51 to 72% of the estimated harvest of game fish in the Tanana Valley and about 34 to 38% of the total estimated fishing effort. During 1996, about 67% of the total harvest of wild and stocked fish in the Tanana Valley was attributed to just two stocked species: rainbow trout and landlocked coho salmon (Howe et al. 1997).

Following are the objectives and a task addressed in this report for Project F-10-13, Job E-3-1(a):

Objective 1: Estimate the abundance of rainbow trout in Craig, Coal Mine #5, and Little Harding lakes such that $\Pr\left(\left|\dfrac{\hat{N}-N}{N}\right| \geq 0.25\right) = 0.05$.

Objective 2: Estimate the age and size compositions of rainbow trout in these three lakes such that $\Pr(|p - P| \geq 0.05) = 0.05$. Age categories are: age 1 and older than age 1. Size categories are: less than 350 mm and 350 mm tip-of-snout to fork-of-tail (FL) and larger.

Task: Obtain lake temperature profiles in selected stocked waters.

Following are the objectives and a task addressed in this report for Project F-10-12, Job E-3-1(a):

Objective 1: For Birch, Quartz, and Chena lakes estimate the proportion of the harvest made up of different cohorts of rainbow trout and coho salmon such that $\Pr(|p - P| \geq 0.05) = 0.05$ for Birch and Quartz lakes, and $\Pr(|p - P| \geq 0.075) = 0.05$ for Chena Lake.

Objective 2: Estimate the proportion of the harvest from Birch Lake made up of coho salmon that were stocked as age 0 fingerlings (1-4 g) and age 1 subcatchables (30 g) such that $\Pr(|p - P| \geq 0.05) = 0.05$.

Task: Determine cost to the creel for coho salmon stocked as fingerling and subcatchable.

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[1] Fishing effort (angler-days) for a location is defined as the estimated number of days fished by all anglers for that location (Mills 1980-1995). Any part day fished by an angler is considered one whole day or one angler-day.

ABUNDANCE AND COMPOSITION OF RAINBOW TROUT IN LAKES MANAGED FOR TROPHY SIZE FISH

In 1994 Region III initiated a program to create fisheries for trophy size rainbow trout in Little Harding Lake (22 ha), Craig Lake (7 ha) and Coal Mine #5 Lake (5 ha) (Figure 2). Special regulations were adopted for these lakes to increase the likelihood of creating successful fisheries. These lakes are open to fishing from 15 May through 30 September. Only unbaited, single-hook, artificial lures and flies may be used. The daily bag and possession limit for rainbow trout is one fish which must be 18 inches, 460 mm total length (TL) or larger.

Success in establishing fisheries for trophy rainbow trout in Little Harding Lake, Craig Lake, and Coal Mine #5 Lake have criteria based on size. For these fisheries to be considered successes, at least half of an age cohort must exceed 14 inches (350 mm FL) by age 4. When stocked these fish are age 1 and average 42 to 70 g. These three lakes were stocked previously with rainbow trout and other species (Appendix A). Prior to 1994 landlocked coho salmon were present in Little Harding Lake. Lake trout and slimy sculpins *Cottus cognatus* are in Coal Mine #5 Lake and lake chubs *Couesius plumbeus* are present in Craig Lake and Little Harding Lake.

The purposes of this study were to estimate the abundance and composition of the rainbow trout populations in these three lakes. This information will be used to evaluate progress towards achieving size criteria.

METHODS

In 1996 and 1995 we marked all rainbow trout that were stocked in Little Harding Lake, Coal Mine #5 Lake, and Craig Lake. Rainbow trout stocked in 1996 were marked by completely excising the right ventral fin and those stocked in 1995 had the adipose fin excised. Rainbow trout stocked in 1997 and those stocked before 1995 were not marked.

Capture

To estimate the abundance of rainbow trout we conducted a two-sample mark-recapture experiment in each lake. For Little Harding Lake and Craig Lake the experiments occurred in May and June before the 1997 fish stocking occurred. For Coal Mine #5 Lake the experiment was conducted in September after the 1997 fish stocking occurred[2].

Fish were captured with fyke nets. The openings of the fyke nets were either 1.2 or 0.9 m sq., hoop size was 0.9 m diameter, mesh size was 9 mm sq., wings were 7.5 m long by 1.2 m deep, and center leads were 30 m long by 1.2 m deep. The center lead, when used, was attached to the center vertical post on the first square frame. We distributed the fyke nets roughly equidistant to each other around the lake perimeters. We used three methods to set the fyke nets. The first method did not use the center lead. We positioned the body of the net parallel to shore with the wings forming a "V". One wing was anchored to shore and a weight was attached to the other

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[2] While it was originally planned to sample prior to stocking to avoid handling new releases, field sampling was delayed due to scheduling conflicts.
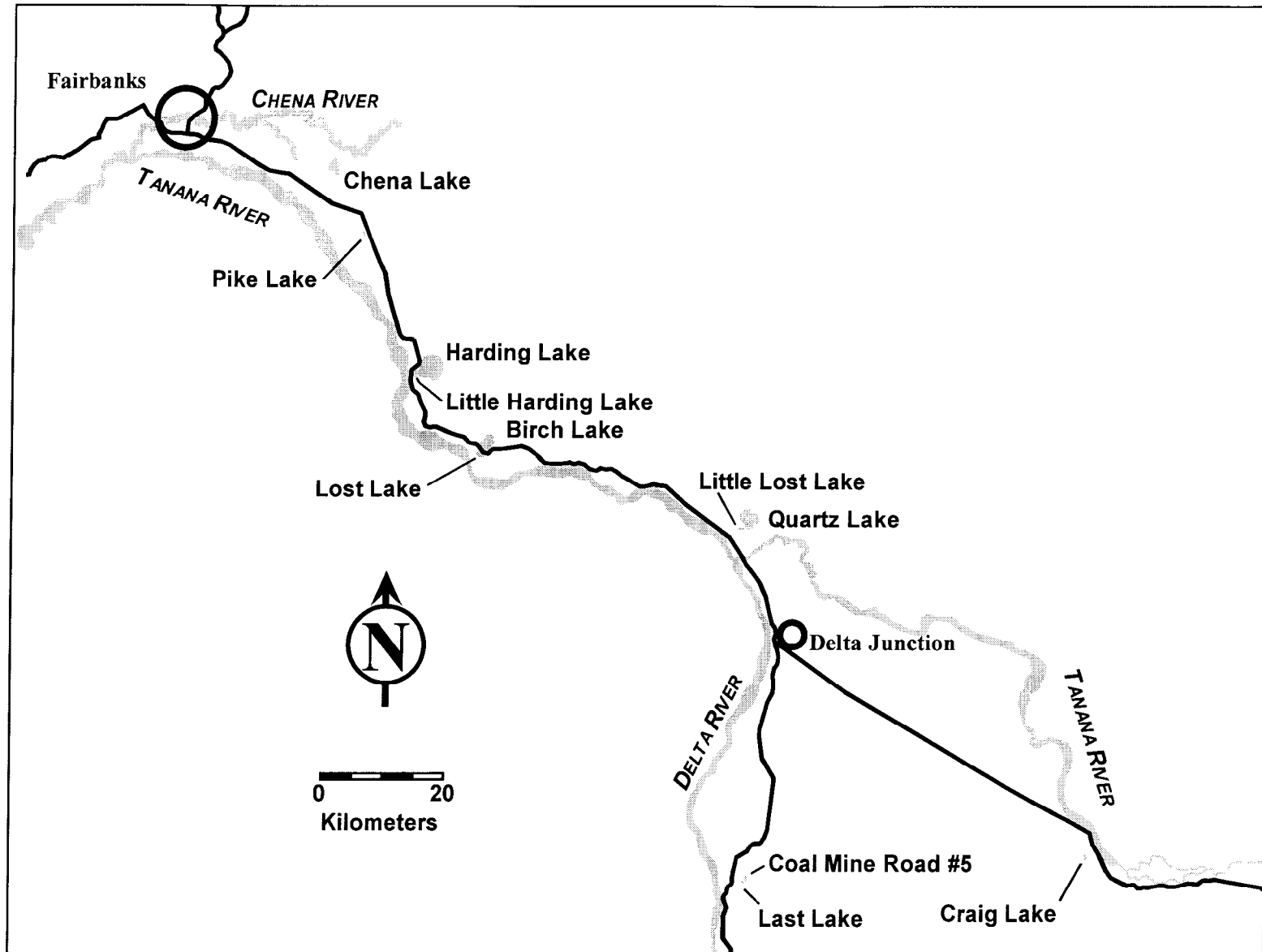
Figure 2.-Tanana Valley study area.

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wing and positioned offshore. Each fyke net was pulled taut from the cod end which was weighted. The fyke nets rested on the lake bottom. Water depth at these sites varied from 1 to 1.8 m. With the second method, center leads were attached to one or two fyke nets in each lake. The unattached end of the center lead was anchored to shore. The fyke nets were set with the center lead perpendicular to shore and wings parallel to shore. The fyke nets rested on the lake bottom in 1 to 2 m of water. In Craig Lake and Little Harding Lake we also set one fyke net in the middle of each lake. Metal tubing was used to stretch the fyke net and maintain proper shape. Floats were attached around the fyke net to keep it from sinking. With this arrangement we used a center lead but did not use the fyke net wings. All fyke nets were baited with unsalted salmon roe.

Each captured fish was marked to identify the event in which it was captured. For marking we used a paper punch (which produces a 7 mm diameter circular hole) to remove a half disk of tissue from the caudal fin from each captured fish. During the marking event (first event) fish were marked in the lower lobe of the caudal fin. All fish captured in the recapture event (second event) were marked in the upper lobe. Any fish captured in the second event without a mark in the lower lobe was classified as unmarked (captured for the first time). Any fish captured more than once during either the marking or recapture events was counted only once per event. We measured all captured fish to the nearest millimeter FL. All length measurements are FL unless noted otherwise.

Data Analysis

The assumptions necessary for accurate estimation of abundance in a closed population and the test of these assumptions are described in Appendices B and C. If significant size bias was detected, separate population estimates were calculated for each size category. The resulting independent estimates were then summed to produce an estimate of abundance.

Bailey's modification of the Petersen estimate (Bailey 1951, 1952; Seber 1982, p.61) was used to estimate the abundance of the entire population or a size category of the rainbow trout population in each of the three lakes:

$$\hat{N} = \frac{n_1(n_2 + 1)}{(m_2 + 1)} \tag{1}$$

where: $\hat{N}$ = the abundance of rainbow trout in a lake; n_1 = the number of rainbow trout marked and released during the first event; n_2 = the number of rainbow trout examined for marks during the second event; and, m_2 = the number of rainbow trout recaptured in the second event.

Variance of this estimator was calculated by (Bailey 1951, 1952):

$$V[\hat{N}] = \frac{(n_1)^2(n_2 + 1)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}. \tag{2}$$

A length frequency distribution of fish with adipose and right ventral fin clips was used to separate the sample into two age/size categories. Only fish captured for the first time were used to generate the distribution. The distribution was examined and an arbitrary point was chosen

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between the two modes that represent the small (usually age 1) and large fish (usually age 2 and older) which gave the lowest number of misclassified individuals.

When the data were adequate, the population abundance was apportioned into age and size categories. Categories were age 2, age 3, and larger than 350 mm. The age 3 category also includes fish older than age 3. The estimated proportion of fish by age category was calculated as:

$$\hat{p}_i = \frac{y_i}{n} \tag{3}$$

where: $\hat{p}$ = the proportion of rainbow trout by age category i; y = the number of rainbow trout sampled that were in age category i; and, n = the total number of rainbow trout sampled.

The unbiased variance of this proportion was estimated as:

$$\hat{V}[\hat{p}_i] = \frac{\hat{p}_i(1 - \hat{p}_i)}{n - 1} \tag{4}$$

The abundance of age i rainbow trout in the population for age i was then:

$$\hat{N}_i = \hat{p}_i \hat{N} \tag{5}$$

The variance for $\hat{N}_i$ in this case was estimated by (Goodman 1960):

$$\hat{V}[\hat{N}_i] = [\hat{p}_i]\hat{N}_i^2 + V[\hat{N}_i]\hat{p}_i^2 - \hat{V}[\hat{p}_i]V[\hat{N}_i \tag{6}$$

Similar methods were used to estimate the number of fish in the population ≥ 350 mm.

RESULTS

Little Harding Lake

During the mark-recapture experiment, 342 rainbow trout were captured and marked in Event 1 and 190 unmarked and 79 marked rainbow trout were captured in Event 2. Of the 532 unique fish captured (Figure 3), 113 had adipose fin clips (fish stocked in 1995) and 230 had right ventral fin clips (fish stocked in 1996). Length frequency distribution by age cohort showed almost complete separation of fish stocked in 1996 from those stocked in 1995 (Figure 4). The sample was divided at 290 mm which separated the greatest number of age 2 fish (≤290 mm) from the rest of the population age 3 and older (>290 mm).

Tests for size bias inferred there was size-selectivity during the marking event but not during the recapture event (Table 1). We followed the scenario under Case II in Appendix C. We estimated the proportion of the population for each age/size category using capture data from the second event (Table 2) and then apportioned the total abundance by category. We estimated 1,157 rainbow trout (SE = 94) in the population of which 864 were age 2, and 293 were age 3 and older (Table 3). We estimated that 80 rainbow trout were 350 mm and larger. Lake chub also were present in the catch, but they were not enumerated.

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Figure 3.-Length frequency histogram for unique rainbow trout captured during the mark-recapture experiment at Little Harding Lake, 1997.
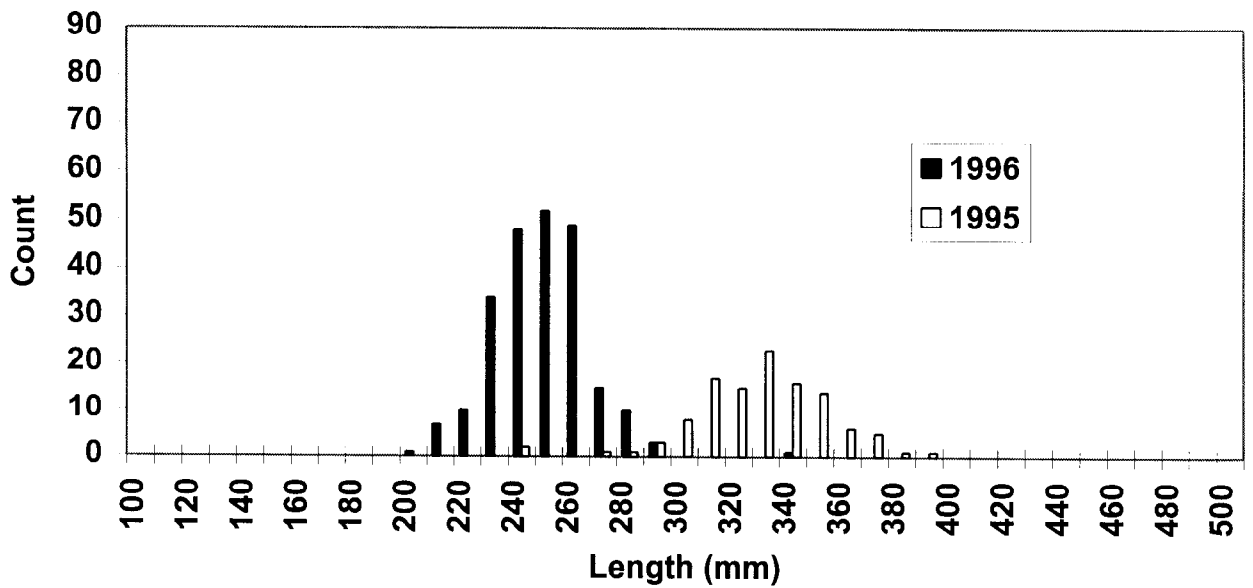
Figure 4.-Length frequency histogram by age class for unique rainbow trout captured during the mark-recapture experiment at Little Harding Lake, 1997. Black bars represent fish stocked in 1996 and white bars are fish stocked in 1995.

Table 1.-Evaluation of size bias during the mark-recapture experiment at Little Harding Lake.

	Test 1		Test 2	
	Recaptured	Not Recaptured	Marked	Not Marked
Age/Size Category:				
Age 2 (≤290 mm)	44	175	44	160
Age 3+ (>290 mm)	35	88	35	30
Results:				
χ^2	3.1		24.4	
p-value	0.078		<0.001	

Table 2.-Rainbow trout captured in Event 2 by age and size category.

Age/Size Category	N	p	SE
Age 2 (≤290 mm)	183	0.75	0.028
Age 3+ (>290 mm)	62	0.25	0.028
≥350 mm	17	0.069	0.016

Table 3.-Abundance estimates for the rainbow trout population in Little Harding Lake.

			95% Confidence Limits	
	Abundance	SE	Lower	Upper
Unstratified	1,157	94	971	1,342
Apportioned:				
Age 2 (≤290 mm)	864	32	801	927
Age 3+ (>290 mm)	293	32	230	355
≥350 mm	80	19	44	117

Craig Lake

During the mark-recapture experiment, 123 rainbow trout were captured in Event 1 and 9 unmarked and 19 marked rainbow trout were captured in Event 2. Unfortunately, fin clips were not noted, so that the sample could not be separated into cohorts. Length frequency distributions did not show any clear separation between age 2 and age 3 cohorts for unique fish (Figure 5). Because we could not distinguish age cohorts we used a two-sample Kolmogorov-Smirnov test to evaluate size bias. We found no indication of size bias during the experiment (Table 4). We estimated 179 fish (SE = 20) in the population (Table 5). We did not estimate the abundance of fish larger than 350 mm because only one captured fish exceeded 350 mm.

Coal Mine #5 Lake

During the mark-recapture experiment 105 rainbow trout were captured and marked in Event 1 (Figure 6 and Table 6). The experiment was stopped because all fish we captured were stocked in 1997 and it was not necessary to estimate their abundance two and one-half months later. We also captured three lake trout that ranged in length from 450 to 480 mm (FL).

DISCUSSION

Of the three lakes in the trophy rainbow trout program Little Harding Lake is the most successful at producing the greatest abundance and the largest fish. Seven percent of the population is equal to or larger than 350 mm. Similarly sized rainbow trout in Quartz Lake make up about 5% of the population (Doxey 1989). Age 0 and age 1 fish from Quartz Lake were excluded from this comparison because these ages are not present in Little Harding Lake. We used the Quartz Lake population for comparison because most anglers consider this lake the best road system fishery in the Interior. Generally, Quartz Lake produces more large rainbow trout ($\geq$350 mm) and the largest rainbow trout. Only one captured fish in Little Harding Lake was larger than the minimum trophy size (460 mm). This is to be expected because fish 460 mm and larger may be harvested.

Originally, in Craig Lake and Coal Mine #5 Lake we wanted to stock small fish (20 to 70 g) as their fin condition and appearance was acceptable to anglers. But survival and growth of the small fish was not acceptable and in 1997 we began stocking larger rainbow trout (158 g) in Craig Lake and Coal Mine #5 Lake to increase survival and growth. Previously, we had wanted to avoid stocking catchable (>100 g) rainbow trout as most have abraded and torn fins which are not acceptable in a trophy fishery. In addition, casual observations over several years suggested that we could expect little or no growth from rainbow trout stocked as catchables. However, last year in Coal Mine #5 Lake we found that the fins of the fish stocked as catchables were not abraded or torn. These fish also grew from an average weight at the time of stocking in June of 158 g (232 mm) to an average weight of 240 g (264 mm) by September. In 1998 we will determine the survival rate of these fish. Given these preliminary results we intend to stock similar size fish in both lakes in 1998.

Each year we have altered stocking methods to improve survival and increase the number of fish larger than 350 mm. We've found that our original stocking plan is working for Little Harding Lake but for Craig Lake and Coal Mine #5 Lake we are now trying other methods. We will continue to strive to meet the criteria for the trophy rainbow trout program because historical catches of stocked rainbow trout in the Interior suggest the criteria are attainable. Failure to
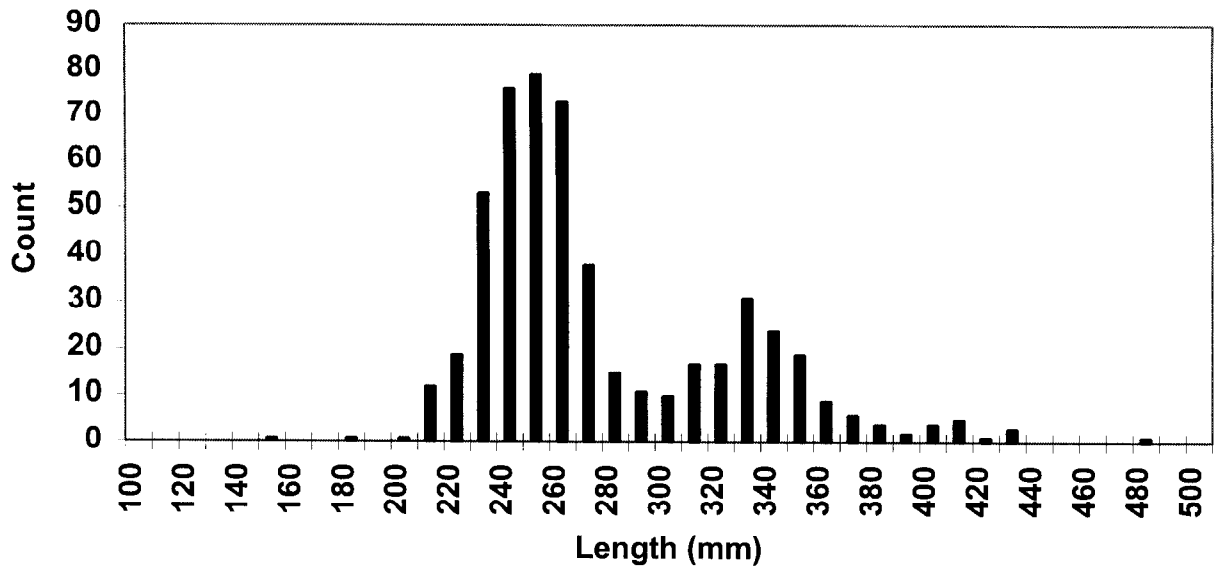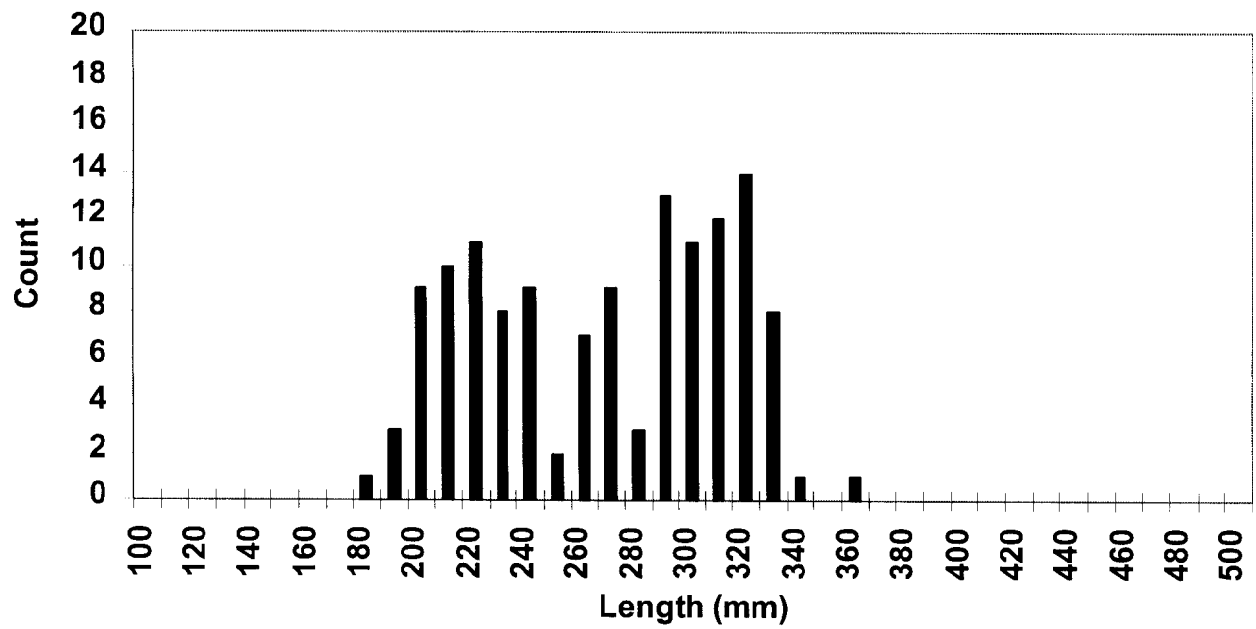
Figure 5.-Length frequency histogram for unique rainbow trout captured during the mark-recapture experiment at Craig Lake, 1997.

**Table 4.-Evaluation of size bias during the mark-recapture experiment at Craig Lake.**

	Test 1	Test 2
K-S statistic	0.58	0.42
p-value	0.62	0.11

Table 5.-Abundance estimates for the rainbow trout population in Craig Lake.

			95% Confidence Limits	
	Abundance	SE	Lower	Upper
Unstratified	179	20	140	218

Table 6.-Rainbow trout captured at Coal Mine #5 Lake during the mark-recapture experiment.

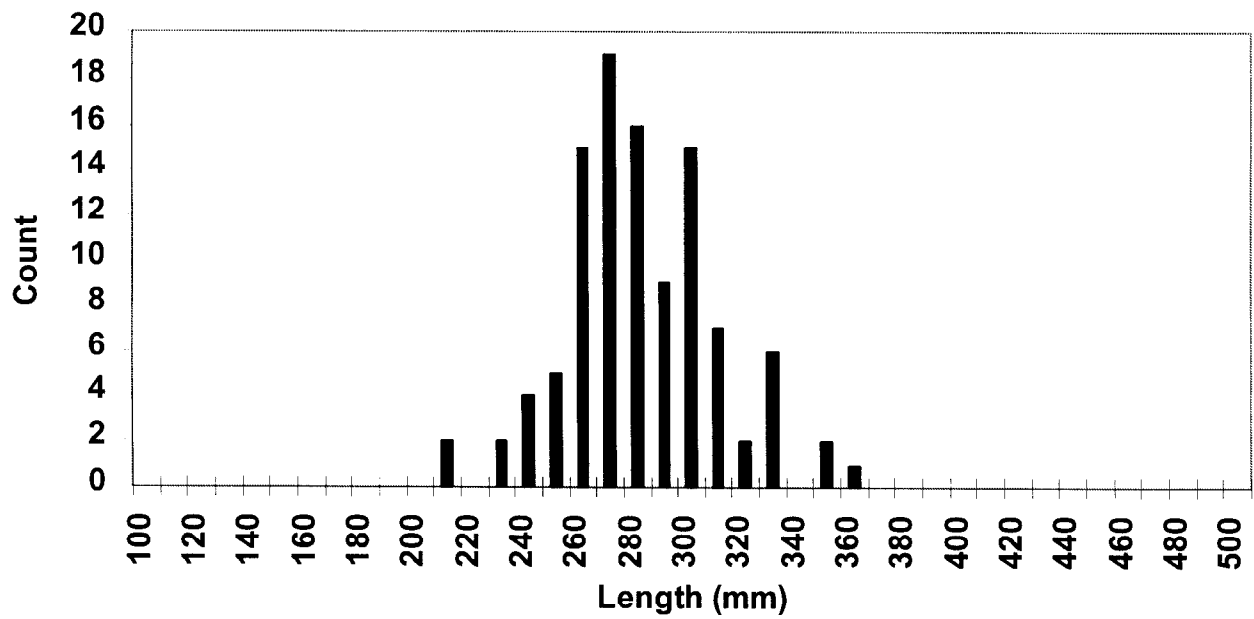|	Marking Event		Recapture Event[a]		
Size Category	Date	Number Marked	Date	Number Unmarked	Number with Marks
All	2-5 Sep	105			

[a] We did not conduct a recapture event

Figure 6.-Length frequency histogram for unique rainbow trout captured during the mark-recapture experiment at Coal Mine #5 Lake, 1997.

achieve the criteria to date may be due to a combination of the following factors, which we are attempting to rectify:

- hooking mortality;
- poor quality products for stocking (fish with abraded fins, and small in size);
- illegal fishing; and,
- poor fish transport conditions, which may contribute to low survival.

In addition, harsh winter conditions may have been a factor. The ultimate success or failure of the trophy rainbow trout program, however, depends on angler support.

LAKE TEMPERATURE PROFILES

State operated fish hatcheries have recently expanded their capacity for producing catchable rainbow trout (about 100 g or 200 mm). This has provided us with an opportunity to experiment with stocking catchable rainbow trout in lakes that don't usually support fish through winter. Some of these lakes are shallow (< 2 m deep) and freeze to the bottom. Other lakes are deeper and don't freeze to the bottom but when ice-covered they often have dissolved oxygen levels too low (< 1 ppm) to sustain overwintering fish. We considered lakes with such characteristics to be "marginal" because they don't support fish year round. In the past we did not stock these lakes with fingerling or subcatchable size fish because these fish usually did not survive to catchable size. Yet, by stocking marginal lakes with catchable size fish we have created popular summer fisheries. The lakes are along the road system and some are in urban areas with easy access.

We now want to expand our program to include other marginal lakes that during summer may approach or exceed the upper temperature limits for survival of rainbow trout and other stocked species. For rainbow trout the upper temperature limit (or maximum survivable temperature) is around 25°C (Hokanson et al. 1977; Bidgood and Berst 1969) while the upper optimum temperature limit is around 18°C (Raleigh et al. 1984). Higher than optimum temperatures usually have an adverse impact on fish health. These temperatures, however, are not absolute. There are anecdotal reports of rainbow trout surviving up to 28°C with mechanical aeration. Rainbow trout have also been reared in stagnant ponds where temperatures exceed 26°C and dissolved oxygen was around 4.5 ppm (Chandrasekaran and Subba Rao 1979). Upper maximum and optimum temperatures probably vary due to local adaptations. If we know that a lake is likely to exceed the maximum temperature or exceed the upper optimum temperature for a significant time then we can alter our stocking method so most fish are stocked and harvested before lethal or optimum temperatures are exceeded. We would then restock after the temperatures fall below lethal levels. Catchable fish represent a significant investment (about $1.75 per fish) and we want to insure that anglers get the full benefit of this resource.

METHODS

We selected four lakes in the Interior to record water temperatures (Table 7). Three of these lakes are marginal lakes that we wish to stock in the future. Last Lake and Little Lost Lake are shallow (<3m) but at different elevations (Table 7). Pike Lake is also shallow (<2m) except for one deep area (~6.7m) that might provide refuge from high temperatures. Lost Lake is typical of lakes that we have stocked for a number of years. It was selected as a control for comparing temperatures with the other three lakes.

Table 7.-Characteristics of four lakes sampled in the Tanana drainage.

Lake	Surface Area (ha)	Depth (m)	Elevation (m)
Last Lake	1	3	763
Little Lost Lake	20	3	290
Pike Lake	3	7	167
Lost Lake (Control)	38	11	252

Water temperature recordings were made using Hobo and Optic Stowaway temperature data loggers (manufactured by Onset Computer Corporation[3]). A set of data loggers was placed in each lake at the deepest known area. All loggers in a set were attached to a single line. A weight and float were attached to opposite ends of the line. We placed data loggers near the bottom of all four lakes to determine if a refuge from lethal temperatures existed. Other data loggers were placed at equal distance intervals between the surface and bottom to determine the presence and depth of lethal temperatures (Table 8). Water temperature was recorded every 30 minutes. Figures 7-10 were generated by plotting the daily maximum temperature.

We used Surfer[4], a computer program, to calculate lake volume above and below specific depths for Last Lake, Little Lost Lake and Pike Lake. Data used for these calculations were obtained during surveys of lake morphology. Depth data for Lost Lake were obtained from a bathometric map.

RESULTS AND DISCUSSION

No temperature measurements made in the four lakes exceeded the upper maximum temperature for rainbow trout (25°C; Figures 7-10). However, in Little Lost Lake the upper optimal temperature (18°C) was exceeded in the entire water column for 45 days (Table 9). In Last Lake, Pike Lake and Lost Lake the upper optimal temperature was exceeded only near the surface (Table 9, Figures 7, 8, and 9). The number of days above the upper optimal temperature was similar for Little Lost Lake and Pike Lake at similar depths. Temperatures for both lakes peaked around 24°C the last week in June. Lost Lake exceeded the upper optimal temperature near the surface for 22 days but did not reach its highest temperature (about 19°C) until the first week in August. Near surface temperature exceeded the upper optimal temperature in Last Lake for 10 days and reached its maximum (about 20°C) the last week in July. However, the data loggers were not installed in Last Lake until mid-July and we may have missed an earlier period when temperatures were warmer.

When temperatures were at their highest no portion of Little Lost Lake was below the upper optimal temperature for rainbow trout and only about 5% of the water volume of Pike Lake and about 57% of the water volume of Last Lake did not exceed the upper optimal temperature. Most of Lost Lake (over 90%) did not exceed the upper optimal temperature.

Our data suggest that high summer temperature should not limit rainbow trout survival in our four study lakes. However, rainbow trout will probably be stressed in Little Lost Lake and Pike Lake because temperatures will be above the optimal limit. Other investigators found that higher than optimal temperatures may cause adverse impacts to catch rates and fish health. When temperatures exceed the upper optimal temperature rainbow trout become stressed and catch rates tend to decline with increasing temperature (McMichael and Kaya 1991). Temperature induced stress may also cause increased susceptibility to disease (Roberts 1975).

Although rainbow trout will tolerate the highest summer temperatures that we measured other species such as Arctic char and lake trout may not survive in Little Lost Lake or Pike Lake which have little or no refuge. The upper maximum temperature for two European strains of Arctic

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[3] Onset Computer Corporation, 536 MacArthur Boulevard. P.O. Box 3450, Pocasset, MA 02559-3450.

[4] Published by Golden Software, Inc.,809 14th Street, Golden Colorado 80401-1866.

Table 8.-Dates of operation for temperature data loggers at four lakes, 1997.

Lake	Date Installed	Removed	Depth (m)	Comment
Last Lake	15 Jun 97	4 Sep 97	0.6	Logger
			1.8	Logger
			2.7	Lake Bottom
Little Lost Lake	29 May 97	29 Sep 97	0.9	Logger
			2.4	Logger
			3.1	Lake Bottom
Pike Lake	5 Jun 97	17 Sep 97	0.8	Logger
			3.0	Logger
			5.8	Logger
			6.7	Lake Bottom
Lost Lake (Control)	26 Jun 97	12 Sep 97	3.8	Logger
			5.3	Logger
			6.7	Logger
			8.2	Logger
			9.6	Logger
			11.0	Lake Bottom
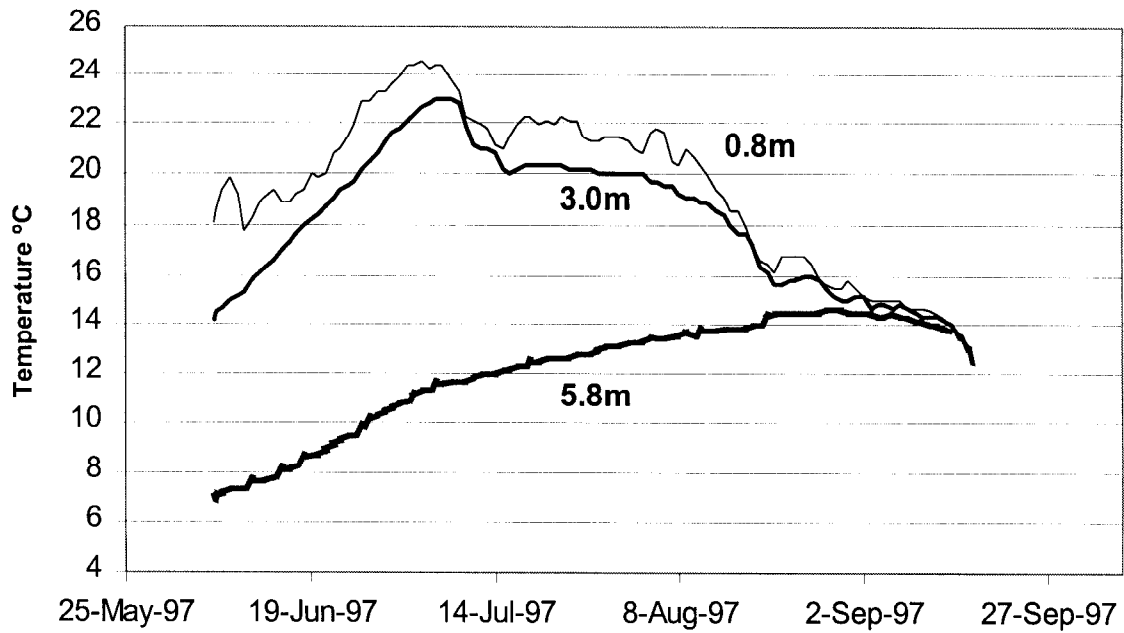
Figure 7.-Temperatures recorded for Pike Lake, 1997.
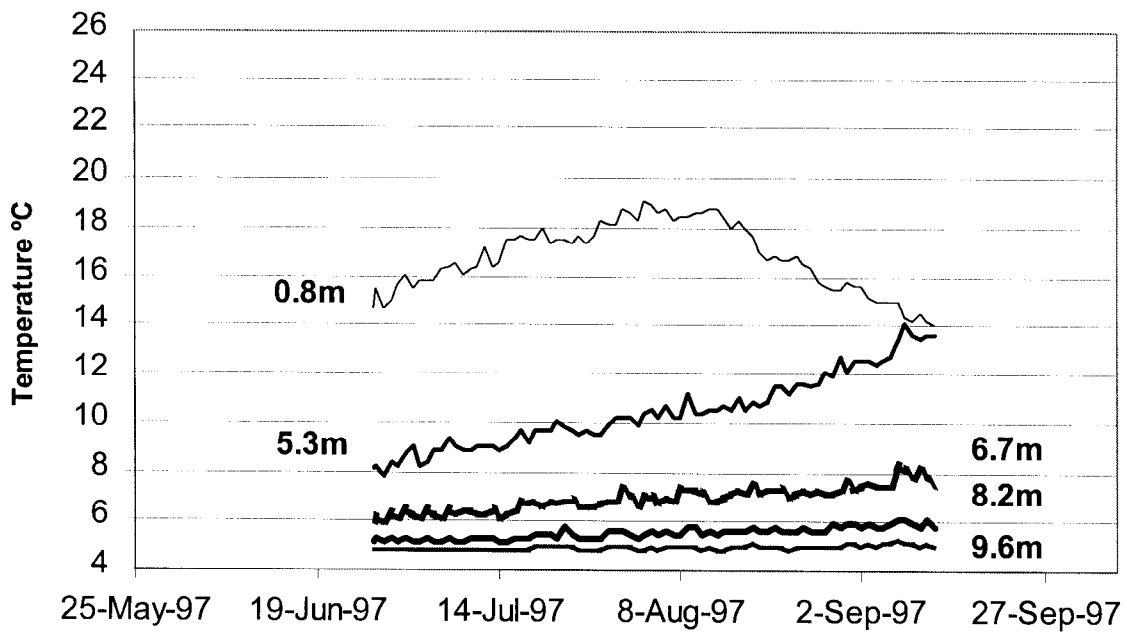
Figure 8.-Temperatures recorded for Lost Lake (Control), 1997.

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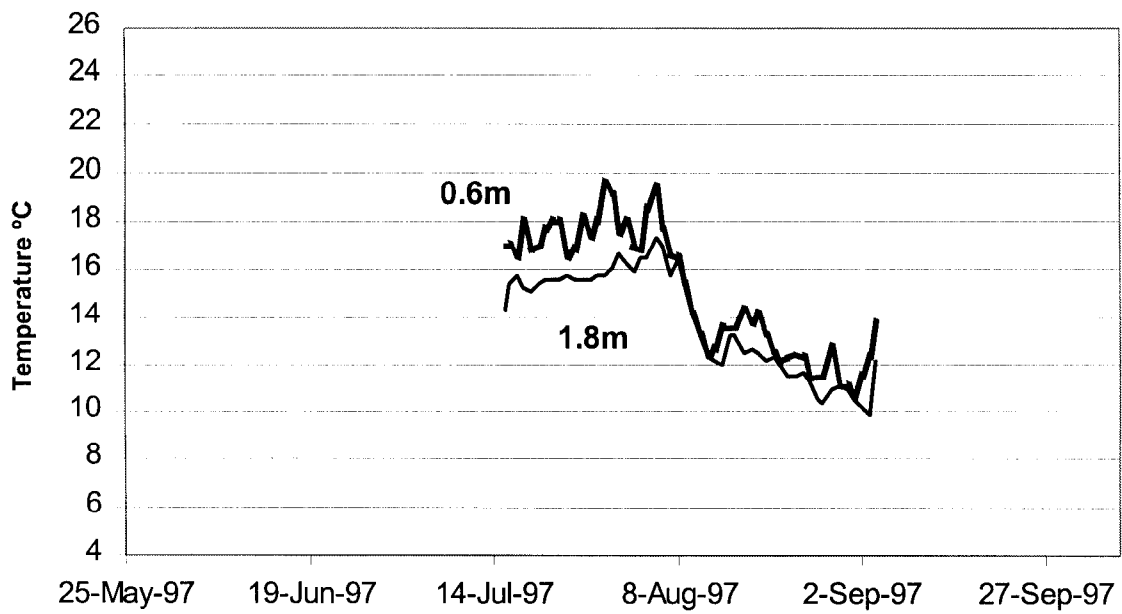
Figure 9.-Temperatures recorded for Last Lake, 1997.
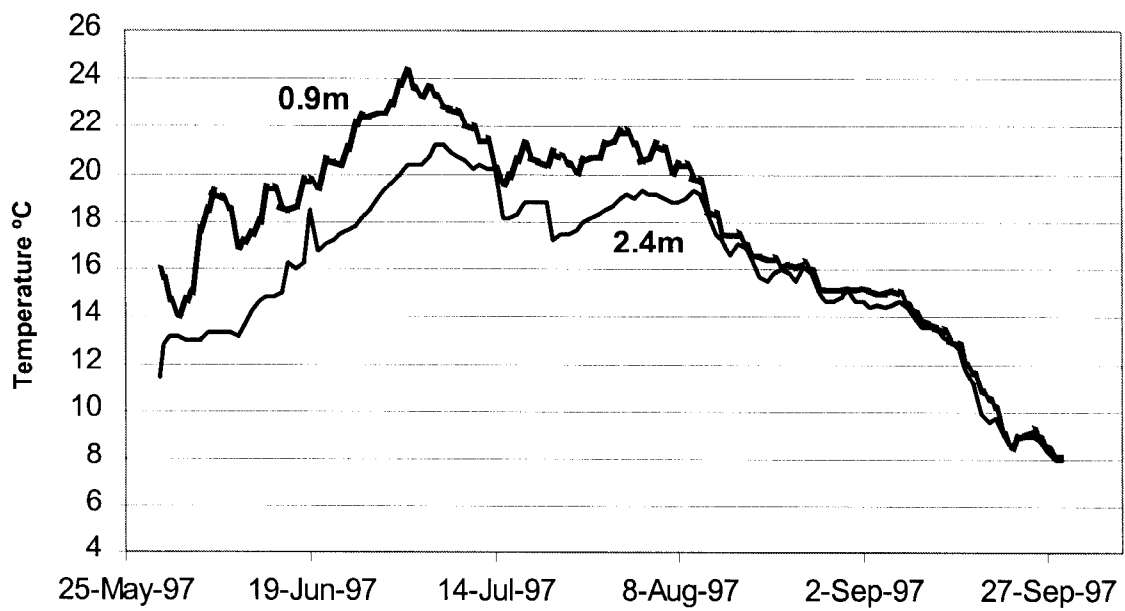
Figure 10.-Temperatures recorded for Little Lost Lake, 1997.

Table 9.-The number of days at which water temperature was above "optimum" (18°C) at four lakes, by depth (in meters), 1997.

Lake	Depth (m)	Days
Last Lake	0.6	10
	1.8	0
Little Lost Lake	0.9	67
	2.4	45
Pike Lake	0.8	72
	3.0	59
	5.8	0
Lost Lake (Control)	3.8	22
	5.3	0
	6.7	0
	8.2	0
	9.6	0

char was 24°C (McCauley 1958). Ultimate upper maximum temperature for lake trout determined experimentally was 23.5°C (Gibson and Fry 1954). Both species, however, have been stocked and have survived in Lost Lake which is deeper and cooler than the other three lakes.

The other stocked species, coho salmon and Arctic grayling, can probably survive the maximum temperatures that we observed. Upper maximum temperature for coho salmon fry determined experimentally is 25°C (Brett 1952), similar to that for rainbow trout. Their optimal temperature is 12 to 14°C, lower than that for rainbow trout. Upper maximum temperature for Arctic grayling, also determined experimentally, ranged from 20 to 25°C (LaPerriere and Carlson 1973).

The marginal lakes that we intend to stock have potential to provide excellent summer fisheries because they are close to population centers and popular recreation areas. However, because of high summer temperatures we need to consider the biological limits of the candidate species, the lake thermal characteristics, and the extent of possible refuge. With planning we can use marginal lakes to provide additional recreational activity for anglers.

CATCH SAMPLING AT BIRCH, QUARTZ, AND CHENA LAKES

Some of the information that ADF&G uses to assess the stocking program for rainbow trout and coho salmon in Birch Lake, Quartz Lake, and Chena Lake is derived from brood tables. Using brood tables, the numbers of fish harvested are calculated from an age/size cohort. A cohort is defined as a group of similar size fish of the same species and age that are stocked in the same stocking event. A stocking event is a release of fish that is unique based on the time and location of the stocking. For example: a cohort of 4g rainbow trout stocked in 1991 is considered different from a cohort of 24g rainbow trout that is stocked in 1991 and both of these cohorts are different from a cohort of 4g rainbow trout that is stocked in 1992. The brood tables require estimates of the total harvest by species and estimates of the cohort composition in the harvest. Estimates of total harvest by species are obtained from a mail survey (the statewide harvest survey or SWHS; Mills 1994), however the SWHS does not provide information on the cohort composition of the harvest. Thus, we directly estimate the cohort composition of the harvest with a catch sampling program. With estimates of total harvest by species from the SWHS and estimates of cohort composition from catch sampling, we can estimate the number of fish that are harvested from a cohort. This data along with stocking costs are then used to calculate the cost-to-the-creel by cohort. This information helps managers to maintain acceptable fisheries at acceptable costs.

METHODS

Catch sampling ran from May 1995 through March 1997 and covered the summer and winter seasons. At least one sampling event was scheduled during one weekend day each month for each of the three lakes. No sampling occurred in the fall and spring when the ice was unsafe. Only anglers which completed fishing were interviewed because we thought that some anglers were more likely to keep larger fish if they were close to filling their limit.

Fish were identified by species and measured to the nearest millimeter (FL). We noted any distinguishing marks such as fin clips or tags and collected a scale sample from each fish. When possible the scales were taken from the area immediately above the lateral line on the left side

and beneath the dorsal fin. Otherwise, scales were taken anywhere they were available above the lateral line. Scales were mounted on glass slides and viewed with a microfiche reader. We determined that the transition from winter to summer circuli would represent one year. Areas of transition are usually easily observed because bands of circuli formed during winter are usually more closely spaced than are bands of circuli formed during summer. Ages were determined by counting the number of transitions starting at the center of the scale and moving outward toward the edge. One person determined the ages for all samples.

From the catch sampling data we calculated the proportion of each age cohort in the harvest using Equations 3 and 4. Separate estimates were made for rainbow trout and coho salmon in each of the three lakes. These estimates are not biased if the proportions of each age cohort in the sample are representative of the proportions of each age cohort in the population and the ages are correctly determined by scale patterns. The estimated proportions by age cohort from catch sampling were then compared to the proportions used in brood tables that apportioned the estimated harvest by age cohort. Methods used to construct the brood tables are explained by Skaugstad et al. (1994).

RESULTS

Age was determined for 311 rainbow trout and 609 coho salmon harvested from Quartz Lake, 293 rainbow trout and 83 coho salmon from Birch Lake, and 126 rainbow trout and 272 coho salmon from Chena Lake. Data collected from chinook salmon harvested from Chena Lake was combined with coho salmon for analysis for two reasons: 1) chinook and coho salmon are not distinguished accurately by the angling public at Chena Lake, so that the harvest estimate as reported in the SWHS is a combination of the two species; and, 2) creel clerks have difficulty in distinguishing between chinook and coho salmon. Length data were obtained from all fish but we were not able to reliably distinguish age cohorts using length frequency analysis. The data were too sparse for any one sampling event and we could not select a point where age cohorts were least likely to be misclassified. Length data from different sampling events could not be combined because sampling was done through time and growth resulted in broad overlap among age cohorts.

The data from catch sampling indicated that more than half the harvest of rainbow trout at Birch Lake and Chena Lake was made up of age 1 fish. More than 80% of the harvest at Quartz Lake was evenly split between ages 2 and 3 (Table 10). The brood tables for all three lakes were setup to have about one half of the harvest of rainbow trout comprised of age 2 fish (Table 11). The remaining harvest in the brood tables was divided somewhat evenly between age 1 and age 3 fish.

The catch sampling data indicated more than 90% of the coho salmon harvest was made up of age 0 and age 1 (Table 10). There were no age 3 fish in the harvest. The brood tables, however, predicted more than 90% of the coho salmon harvested from each of the three lakes should be age 2 and age 3 (Table 11). Age 1 fish made up less than 10% of the predicted harvest and no age 0 fish were predicted to be in the harvest.

Table 10.-Catch sample statistics for rainbow trout and coho salmon captured at Birch, Quartz, and Chena lakes, 1995-1997.

Location	Statistics	Rainbow Trout				Coho Salmon		
		Age 1	Age 2	Age 3	Age 4	Age 0	Age 1	Age 2
Quartz Lake	P	0.15	0.40	0.41	0.048	0.53	0.39	0.089
	SE	0.020	0.028	0.028	0.012	0.020	0.020	0.012
Birch Lake	P	0.53	0.38	0.089	<0.01	0.36	0.61	0.024
	SE	0.029	0.028	0.017	0.0034	0.053	0.054	0.017
Chena Lake	P	0.64	0.29	0.071		0.28	0.72	<0.01
	SE	0.043	0.040	0.023		0.027	0.027	0.0052

Table 11.-Summary of brood tables showing the estimated proportions by age cohort for rainbow trout and coho salmon harvested from Birch, Quartz, and Chena lakes, 1991-1993.[a]

Location	Year	Rainbow Trout				Coho Salmon			
		Age 1	Age 2	Age 3	Age 4	Age 0	Age 1	Age 2	Age 3
Quartz Lake	1994	0.20	0.80	0	0	0	0.13	0.31	0.56
	1995	0.13	0.67	0.20	0	0	0.10	0.78	0.12
	1996	0.12	0.58	0.30	0	0	0.049	0.13	0.82
	Average	0.15	0.68	0.17	0	0	0.093	0.41	0.50
Birch Lake	1994	0.19	0.55	0.26	0	0	0.092	0.59	0.33
	1995	0.24	0.52	0.24	0	0	0.042	0.83	0.13
	1996	0.18	0.60	0.22	0	0	0.032	0.66	0.31
	Average	0.20	0.56	0.24	0	0	0.053	0.69	0.26
Chena Lake	1994	0.12	0.59	0.17	0.12	0	0.12	0.38	0.50
	1995	0.09	0.34	0.35	0.22	0	0.089	0.80	0.11
	1996	0.12	0.59	0.17	0.12	0	0.013	0.60	0.39
	Average	0.11	0.51	0.23	0.15	0	0.073	0.59	0.33

[a] Data are from Skaugstad et al. (1994).

DISCUSSION

When we designed the brood tables we made several assumptions about the age/size composition of fish in the harvest. Our assumptions did not accurately reflect the estimated age compositions that we found through recent catch sampling of the harvest for rainbow trout and coho salmon. We found more than one-half of the harvests of rainbow trout from Birch Lake and Chena Lake were comprised of age 1 while the brood tables predicted most of the harvest would be comprised of age 2. For Quartz Lake age 2 and age 3 contributed equally to the rainbow trout harvest but the brood tables predicted age 2 would comprise most of the harvest. For all three lakes coho salmon were harvested one year earlier than predicted by the brood tables.

Differences between the estimated age composition of the harvest and the predicted compositions of the brood tables may be the result of recent changes made to the stocking program. The assumptions that we made to create the brood tables were based on observations and stocking practices more than five years old. We are now stocking larger age 0 and age 1 rainbow trout and coho/chinook salmon in Birch Lake and Chena Lake. These fish probably enter the fishery sooner than the same age fish stocked at a smaller size.

The size of fish stocked into Quartz Lake has not changed. However, the differences between the estimated and predicted age compositions are considerable. These differences probably indicate that our original assumptions about the age composition of the harvest were incorrect, the fishery has changed, or some combination of both. Because these fisheries may have changed, it may not be appropriate to use the age compositions from this study to reconstruct the brood tables for the years prior to 1995. As long as current stocking methods remain consistent year to year we will use the estimated age compositions from this study to calculate brood tables from 1995 on.

COST TO THE CREEL COMPARISON FOR COHO SALMON STOCKED AS FINGERLING AND SUBCATCHABLE

The ADF&G fish hatchery at Fort Richardson is now producing subcatchable (~30g) in addition to fingerling (1-4g) coho salmon. We have observed that a higher proportion of fish stocked as subcatchables survive to a catchable size compared to fish stocked as fingerlings. Subcatchables, however, cost more to produce because they use more hatchery resources for a longer time. Fingerling coho salmon are usually stocked in June and subcatchables, which require additional time for rearing, are stocked in the fall. To justify the additional cost of producing subcatchables they must have a higher return-to-the-creel. The purpose of this project was to compare the relative cost to the creel for coho salmon that were stocked as subcatchables and fingerlings.

METHODS

In 1995 and 1996 we stocked 55,200 subcatchable coho salmon that had been marked at the hatchery by completely removing the adipose fin. We also stocked about 84,900 unmarked fingerling coho salmon during this period. During the 1996-97 winter fishery we monitored the harvest and enumerated the marked and unmarked fish. This study was conducted simultaneously with the study *Catch Sampling at Birch, Quartz, and Chena Lakes*. Scale pattern analysis (as described previously) was used to distinguish age 0 and age 1 unmarked coho salmon from previous stockings of unmarked fingerlings. The cost of producing fingerling and

subcatchable coho salmon were obtained from a schedule prepared by ADF&G showing typical costs associated with producing different size fish in the ADF&G hatchery program.

RESULTS AND DISCUSSION

Of 72 coho salmon examined in the creel, 55 had been stocked as subcatchables (p=0.76, SE=0.05). The other 17 fish had been stocked as fingerlings. The hatchery cost to produce a fingerling was $0.04 while a subcatchable was $0.27. A cost/benefit analysis shows coho salmon stocked as fingerlings have a lower cost-to-the-creel (Table 12). For subcatchables to perform as well or better than fingerlings the catch ratio must increase to 4.4 or higher (assuming cost per fish does not change). This means for every 17 fish that we observe in the harvest that had been stocked as a fingerling we should expect to see at least another 75 fish that had been stocked as a subcatchable. Based on these results we should use fingerling coho salmon for stocking Birch Lake.

Table 12.-Cost/benefit analysis for coho salmon stocked as fingerlings and subcatchables.

Stocking Size	Cost per Fish	Number Stocked	Stocking Cost	Number in Catch
Fingerling	$0.04	84,900	$3,396	17
Subcatchable	$0.27	55,200	$14,904	55
Ratio			**4.4**	**3.2**

ACKNOWLEDGMENTS

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APPENDIX A

Appendix A.-Stocking history for the Trophy Lakes, 1990-1997.

Location	Species	Stocking Date	Number Stocked	Age[a]	Sex[b]	Weight (g)	Brood Year	Mark
Craig L	LT	31-May-91	3,500	F		3.9	90	
Craig L	RT	6-Aug-91	4,086	F		2.0	91	
Craig L	RT	20-Jul-93	3,500	F		1.6	93	
Craig L	RT	14-Jun-94	850	C	AF	70.0	94	
Craig L	RT	21-Jun-95	949	S	MF	54.0	94	AD
Craig L	RT	10-Jul-96	550	S	MF	66.1	95	RV
Craig L	RT	12-Jun 97	390	C	MF	158.5	96	
Craig L	RT	12-Jun 97	246	C	AF	87.4	96	
Coal Mine #5 L	LT	29-May-91	2,600	F		3.6	90	
Coal Mine #5 L	RT	16-Jul-92	2,600	F		1.6	92	
Coal Mine #5 L	AC	1-Jul-93	2,600	F		12.0	92	
Coal Mine #5 L	RT	14-Jun-94	750	C	AF	70.0	94	
Coal Mine #5 L	RT	21-Jun-95	450	S	MF	54.0	94	AD
Coal Mine #5 L	RT	10-Jul-96	450	S	MF	77.1	95	RV
Coal Mine #5 L	RT	12-Jun-97	471	C	MF	158.5	96	
L Harding L	SS	16-Jul-90	3,600	F		2.7	89	
L Harding L	RT	24-Jul-90	1,000	F		1.6	90	
L Harding L	RT	24-Jul-91	3,600	F		1.8	91	
L Harding L	RT	22-Jul-92	11,000	F		1.1	92	
L Harding L	SS	21-Jun-93	7,700	F		0.9	92	
L Harding L	SS	24-Jun-93	14,300	F		0.8	92	
L Harding L	RT	18-May-94	2,838	S		42.0	94	
L Harding L	RT	21-Jun-95	1,300	S	MF	54.0	94	AD
L Harding L	RT	11-Jul-96	100	B	MF	800.0	93	
L Harding L	RT	18-Jul-96	1,750	S	MF	67.0	95	RV
L Harding L	RT	8-Jul-97	1,400	C	MF	65.0	96	
L Harding L	RT	8-Jul-97	74	B	MF	800.0	94	

[a] C = catchable; F = fingerling; S = subcatchable.

[b] AF = All female; MF = male and female.

APPENDIX B

Appendix B.-Assumptions necessary for accurate estimation of abundance in a closed population.

The assumptions necessary for accurate estimation of abundance in a closed population are as follows (taken from Seber 1982):

1. the population is closed (no change in the number of rainbow trout in the population during the estimation experiment; i.e. there is no immigration, emigration, births or deaths);

2. all rainbow trout have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked rainbow trout mix completely between marking and recapture events;

3. marking of rainbow trout does not affect their probability of capture in the recapture sample;

4. rainbow trout do not lose their mark between the marking and recapture events; and,

5. all marked rainbow trout are reported when recovered in the recapture sample.

For assumption 1 no immigration or emigration is assured because the lakes do not have inlets or outlets. The second half of assumption 1 is also assured because rainbow trout do not reproduce in these lakes. If during the study the probability of death is equal for each fish then the abundance estimate is germane to the first event. To minimize the likelihood of higher mortality rates for marked fish, all captured fish were handled carefully and any fish that showed signs of severe stress was marked by excising a small portion of the upper caudal lobe prior to release. Any fish given such a mark was not considered part of the mark-recapture experiment. A hiatus of two weeks was sufficiently long to minimize the effect of previous capture on capture probability as related to assumption 2. Validity of assumptions 2 and 3, relative to sampling induced selectivity of fish, was tested with Chi-squared tests generated from length data collected during the marking and recapture events (Appendix C). A length frequency histogram was used to distinguish size classes. The first hypothesis tested was that all marked rainbow trout have the same probability of capture in the recapture sample. Probability of capture usually differs by the size of rainbow trout, especially when a size selective gear is used. Fyke nets should not be size selective, however, they are typically placed near shore in shallow water where part of the population may not frequent. Given this situation the probability of capture will not be the same for all fish. If this test was significant, the recapture sample was biased and the data were partitioned into size classes. Population estimates were generated for each size class and these independent estimates were summed to estimate the abundance of the entire population. If the test does not detect a significant difference, the data were not partitioned and a single population estimate sufficed.

The second hypothesis tested was that rainbow trout captured during the first event had the same length frequency distribution as fish captured in the second event. There were four possible outcomes of these two tests; either one or both of the samples were biased or neither were biased. Possible actions for data analysis are outlined in Appendix C.

Assumption 4 was assured because there is not sufficient time for excised tissue to grow back.

Assumption 5 was assured because of rigorous examination of all fish for fin clips.

Complete mixing of marked and unmarked rainbow trout between the first and second events was assumed to be occurring during the experiment. To promote mixing and give each fish an equal chance of being captured there was a two week hiatus between the first and second events (except for Craig Lake) and fish captured in the first event were released towards the middle of the lake.

APPENDIX C

Appendix C.-Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first χ^2 (or K-S) test[a]	Result of second χ^2 (or K-S) test[b]

__Case I[c]__

Fail to reject H_o Fail to reject H_o

Inferred cause: There is no size-selectivity during either sampling event.

__Case II[d]__

Fail to reject H_o Reject H_o

Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.

__Case III[e]__

Reject H_o Fail to reject H_o

Inferred cause: There is size-selectivity during both sampling events.

__Case IV[f]__

Reject H_o Reject H_o

Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

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[a] The first χ^2 test is based on a contingency table to examine the effect of variable catchability of marked fish captured during the second event for various size/age categories. The contingency table is made up of marked fish that are captured and not captured in the second event. H_o for this test is: The probability of capture in the second event for marked fish is constant across the various categories.
or
The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second χ^2 test is based on a contingency table to examine the effect of variable catchability in the first event for given size/age categories. The contingency table is made up of marked and unmarked fish captured in the second event. H_o for this test is: The probability of capture in the first event is constant across the various categories.
or
The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.
If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.
If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

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APPENDIX D

Appendix D.-Archive files for data collected during studies covered in this report.

File Name	Description
TROPHY97.XLS	Data sets for fish captured during study of rainbow trout in lakes managed for trophy size fish. Capture locations are Coal Mine #5 Lake, Craig Lake and Little Harding Lake.
THERMOGRAPHS.XLS	Data sets collected during study of lake temperature profiles. Lakes in the study are Little Lost Lake, Lost Lake, Last Lake and Pike Lake.
CATCHAGE95-97.XLS	Data sets for fish sampled during creel surveys at Birch Lake, Quartz Lake and Chena Lake.

Data files are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska, 99518-1599.